

# **HOW CLOSE TO ZERO CAN VOLVO CARS GET BY 2020? AN ANALYSIS OF FATAL CRASHES WITH MODERN VOLVO PASSENGER CARS IN SWEDEN**

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## **ABSTRACT**

In 2008 Volvo Cars set out its vision - by 2020 no one should be killed or seriously injured in or by a new Volvo car. Today, 2020 is very close and it is possible to assume most of the safety technologies that will likely be fitted in Volvo cars by then. The objective of the present study was to estimate how close to zero fatalities Volvo Cars can get in Sweden by 2020.

The Swedish Transport Administration (STA) carries out in-depth studies of all road fatalities in Sweden. Cases involving at least one modern Volvo car were extracted for the period 2010-2017 (MY 2010 and onwards, excluding the C30, S40 and V50 models) and analyzed retrospectively (n=62). The yearly average number of fatalities in Sweden during 2010-2017 was 2.8 for occupants in Volvo cars and 5.0 for either occupants in other vehicles or VRUs impacted by Volvo cars, respectively.

The actual fitment of safety technologies was investigated among the Volvo cars involved in these crashes. The basic assumption was that by 2020 the boundary conditions in each crash would be unchanged, but the Volvo car would be a MY 2020 and therefore would be fitted with the same safety technologies as the V60 MY 2019. An assessment was then made of whether a certain technology could have prevented the crash or substantially reduced the crash severity in 2020. Cases involving extreme violations such as excessive speeding, were included in the analysis but presented separately. It was also assumed that no major improvements in crashworthiness would be introduced between the analyzed Volvo models and Volvo cars MY 2020.

The analysis showed that almost half of the fatalities in and by Volvo cars could have been prevented with the safety technologies fitted on the V60 MY 2019. It was also found that most of the fatalities that could not be prevented with a V60 MY 2019, occurred in crash scenarios where at least one safety technology was relevant, although the current performance was estimated not to be sufficient to prevent the fatality. Only three cases occurred in crash scenarios without any relevant existing safety technology.

It should be kept in mind that these results were based on retrospectively upgrading already relatively safe cars to the following generation. This suggests that reducing fatalities by almost 50% through the introduction of only one new car generation would be a very impressive achievement. It is also important to note that these results were based on the assumption that the road infrastructure, speed limit and crash opponents would be unchanged. Clearly, taking safety improvements in the road infrastructure and other vehicles into account would result in an even higher reduction of fatalities in and by Volvo cars by 2020.

In conclusion, regardless of whether Volvo's vision will be achieved by 2020 or not, it is very important to set road safety targets, develop new solutions and follow up the results, also for a car manufacturer.

## INTRODUCTION

Setting targets for the number of fatalities and serious injuries in road traffic crashes has been a tradition for jurisdictions, regions and even globally. Since some years, starting in Sweden in 1997, long-term targets have been set based on Vision Zero. In this vision, the ultimate objective is to develop the entire road transport system to be forgiving, by adopting the principle of the failing and fragile human. The design philosophy is to reduce human mistakes, but if they still occur, the system is forgiving. Several layers of technology must be in place to bring driving back to normal, or prepare for a crash that is survivable and not causing long-term injury. To develop a safe road transport system is a matter of merging a number of factors and components of the system together to act in a way that protects the road users. In particular the amount of kinetic energy, i.e. speed, must be limited to the inherent safety of the protective systems.

Vision Zero, sometimes called Safe System, has been adopted by many stakeholders across the world. Individual countries, the EU, the UN, the US, and many cities nowadays develop their transport systems according to the policy, and for example the EU has even set a year for reaching "close to zero deaths" (2050; EC, 2011). Already in 2008, Volvo Cars set a Vision Zero target, and also set a date for when it should be reached (model year 2020; Volvo Cars, 2009). In doing so, Volvo was the first car manufacturer to set a target of this kind, and still seems to be alone in having a target year for its completion. Therefore, it is of great interest to estimate how close to zero Volvo Cars will be in 2020. From the issue of automated cars it is also of great interest to study the latest safety systems, although a manually driven car is far from automated driving when it comes to the "freedom" of the driver to drive the car outside its design envelope including basic traffic rules.

The target by Volvo Cars does not seem to be set with any restrictions concerning risk factors, when and where it applies. In some of the communication it has even been expressed in a way that it also includes road users outside the Volvo car, i.e. "seriously injured or killed in or by a new Volvo" (Volvo Cars, 2009). In a broader context, the value of the vehicle to solve almost the entire road safety problem is at stake, and therefore needs to be studied carefully as it would have a massive impact on the choice, investments and management of safety countermeasures.

## OBJECTIVE

The objective of the present study was to estimate how close to zero fatalities Volvo Cars can get in Sweden by 2020.

## DATA SOURCE

The Swedish Transport Administration (STA) has been carrying out in-depth studies of all road fatalities since 1997. Crash investigators at the STA systematically inspect the vehicles involved and record direction of impact, vehicular intrusion, seat belt and helmet use, airbag deployment, tyre properties, etc. The crash site is also inspected to investigate road characteristics, collision objects, etc. Further information is provided by forensic examinations, witness statements from the police and reports from the emergency services (STA 2005). Collision speeds are generally derived by vehicular deformation, and the initial driving speed is mostly based on eye-witness accounts, brake skids, etc. Pre-crash braking is also coded based on eye-witness accounts, brake and skid marks. The final results of each investigation are normally presented in a report. Because all fatal crashes are included in the sampling criterion, the material can be considered fully representative for Swedish road fatalities and possibly even for Northern Europe at large.

## MATERIAL AND METHODS

Fatal crashes involving at least one Volvo car of model year (MY) 2010 and onwards were extracted for the period 2010-2017. The C30, S40 and V50 models were excluded as they were based on older platforms with limited safety technologies. This selection process resulted in a total of 57 cases: 18 fatal crashes with 22 fatally injured occupants in modern Volvo cars were found. Further 39 fatal crashes with 40 fatally injured occupants in other motor vehicles or vulnerable road users (VRU) were identified (see Table 1). The yearly average number of fatalities in Sweden during 2010-2017 was 2.8 for occupants in Volvo cars and 5.0 for either occupants in other vehicles or VRUs impacted by Volvo cars, respectively.

**Table 1.**  
**Number of fatalities in and by Volvo cars MY  $\geq$  2010 in Sweden during 2010-2017. C30, S40/ V50 models excluded**

road user type	fatalities <u>in</u> Volvo cars	fatalities <u>by</u> Volvo cars
car drivers	16	17
car passengers	6	1
pedestrians		12
PTW riders		6
cyclists		2
electric wheelchairs		1
HGV occupants		1
Total	22	40
<b>average per year (2010-2017)</b>	<b>2.8</b>	<b>5.0</b>

The actual fitment of safety technologies (for instance rear-end Autonomous Emergency Braking, Lane Departure Warning etc.) for each of the Volvo cars involved in these 57 crashes was investigated and retrospectively upgraded to the equipment of the V60 MY 2019. In other words, the analysis was based on the assumption that by 2020 the boundary conditions in each crash would be unchanged (i.e. the road infrastructure, speed limit and crash opponents would be the same). However, the Volvo car would be a MY 2020 and therefore would be fitted with the same safety technologies as the V60 MY 2019. These are as follows (Volvo Cars 2019a):

- Active Bending Lights
- Adaptive Cruise Control (ACC)
- Autonomous Emergency Braking (AEB)
  - Low-speed rear-end
  - Left-turn crossing with oncoming traffic
  - Head-on
  - Large animal detection
  - Pedestrian and cyclist detection
  - Post-crash
- Blind Spot Detection
- Cross Traffic Alert with AEB
- Driver Alert Control
- E-call
- Electronic Stability Control (ESC)
- Emergency Steering Support (individually brakes one or two wheels to reinforce the steering wheel input in an evasive maneuver)
- Forward Collision Warning (FCW)
- Lane Support (Oncoming Lane Mitigation and Lane Keeping Aid)
- Rear Collision Warning
- Run-Off road Mitigation
- Seat Belt Reminder (SBR)
- Tire Pressure Monitoring System

An assessment was then made of whether at least one of the above technologies could have prevented the crash or substantially reduced the crash severity. To handle the issue of subjectivity in such assessments, each case was discussed in a group of at least three road safety analysts until consensus was reached. Cases involving extreme violations were included in the analysis but analyzed separately. In the present study, extreme violations were defined as clear and intentional violations of basic traffic rules, for instance extreme speeding or unbelted occupants despite SBRs. It was also assumed that no major improvements in crashworthiness would be introduced between the analyzed Volvo models and Volvo cars MY 2020.

## RESULTS

The majority of the fatal crashes involved the S80/V70/XC70 models (60%, see Table 2). All of the analyzed cars were fitted with ESC and SBR in the front seats. While 65% were fitted with low-speed AEB for rear-end

collisions (City Safety), only 13% had the optional Driver Support safety package including a number of technologies such as ACC, Lane Departure Warning (LDW) and/or Lane Keeping Assist (LKA), Driver Alert Control, Pedestrian Detection and Blind Spot Detection (see Table 3). The V40s were fitted with pedestrian airbag.

**Table 2.**  
*Number of Volvo car models MY  $\geq$  2010 included in the analysis*

Volvo model	fatalities <i>in</i> Volvo cars	fatalities <i>by</i> Volvo cars
S60/V60	7	5
S80/V70/XC70	14	23
V40	1	5
XC60		6
XC90 MY 2016		1
<b>Total</b>	<b>22</b>	<b>40</b>

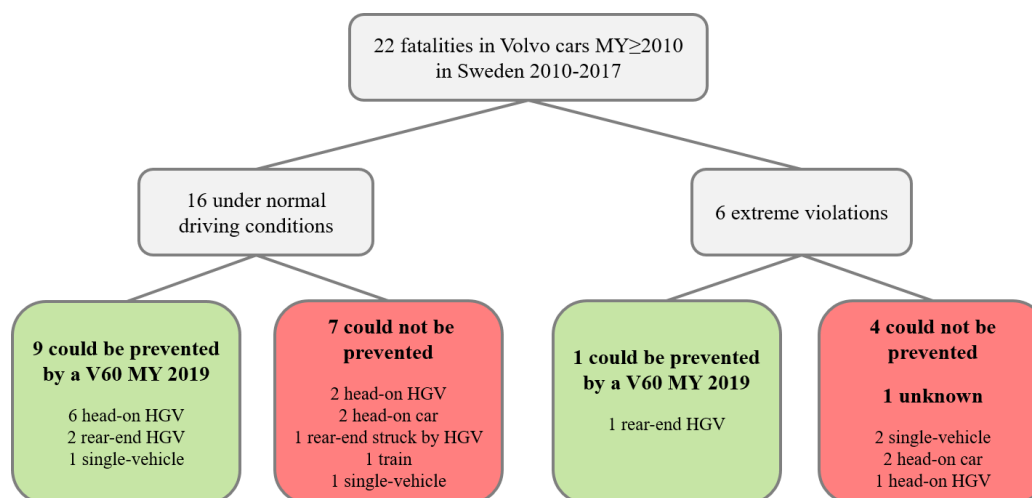
**Table 3.**  
*Fitment of safety technologies among the Volvo cars included in the analysis*

Safety technology	fatalities <i>in</i> Volvo cars	fatalities <i>by</i> Volvo cars	% fitment
ESC	22	40	100%
SBR front seats	22	40	100%
City Safety (AEB low-speed rear-end)	13	27	65%
Driver Support Package	1	7	13%

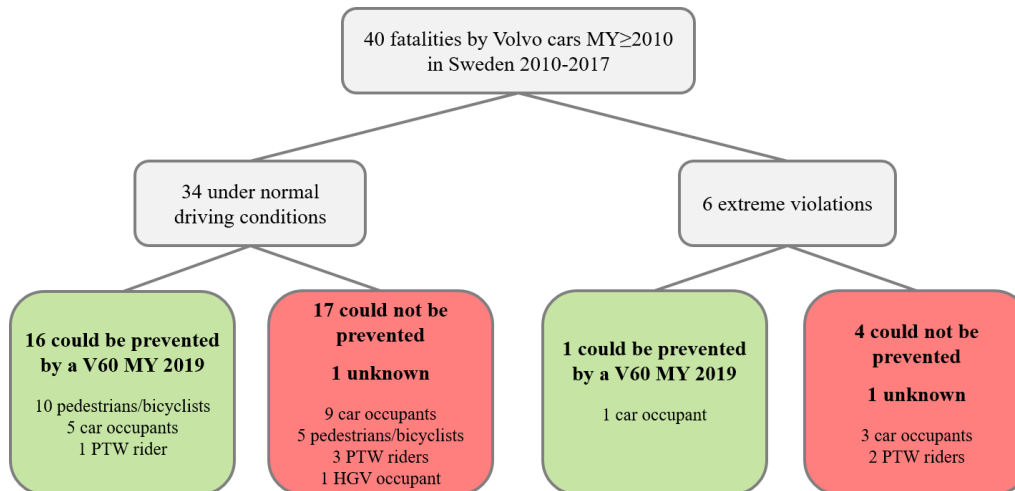
It was also found that 37% of the Volvo cars were privately owned. Further 57% were either company cars, leased cars or rental cars. Information on ownership was missing in 6% of cases.

The analysis showed that 16 of the 22 fatalities in Volvo cars occurred under normal driving conditions (73%), see Figure 1. The remaining six cases involved clear violations, mostly excessive speeding. It was assessed that a total of ten fatalities (45%) could have been prevented with a Volvo V60 MY 2019 safety equipped vehicle (9 of these occurred under normal driving conditions). In one case, this assessment was not possible due to partly missing information.

With regard to the fatalities by Volvo cars, similar results were found: 34 fatalities occurred under normal driving conditions (85%, see Figure 2). A total of 17 fatalities (42%) were assessed to be potentially prevented by a Volvo V60 MY 2019 (16 of these occurred under normal driving conditions). In two cases, the available information was not sufficient to make such an assessment.



**Figure 1.** Number of fatalities *in* Volvo cars MY  $\geq$  2010 in Sweden during 2010-2017 that could have been prevented in a V60 MY 2019.



**Figure 2. Number of fatalities by Volvo cars MY ≥ 2010 in Sweden during 2010-2017 that could have been prevented by a V60 MY 2019.**

The reductions shown in Figure 1 and 2 would correspond to approximately 1.4 fatalities in Volvo cars and 2.6 by Volvo cars per year in Sweden. The technologies that could have prevented the fatalities in and by Volvo cars are listed in Table 4. Among fatalities in Volvo cars, the most effective technology was Lane Support (n=7), followed by ACC and Driver Alert Control (n=3, respectively). However, it is important to note that several crashes could have been prevented by more than one technology, which explains why the sum of the individually prevented fatalities shown in Table 3 is higher than 10.

Among fatalities by Volvo cars, the most effective technology was estimated to be AEB with pedestrian and cyclist detection (n=10), followed by AEB head-on (n=5). In two cases, it was estimated that the combination of AEB with pedestrian detection and improved crashworthiness could have prevented the fatality, at least theoretically. However, such assessment was considered too uncertain to be included among the prevented fatalities.

**Table 4.**  
**Number of fatalities that could have been prevented by different technologies**

	<b>fatalities <u>in</u> Volvo cars</b>	<b>fatalities <u>by</u> Volvo cars</b>
ACC	3	
AEB head-on	2	5
AEB post-crash		1
AEB with large animal detection		1
AEB with pedestrian and cyclist detection		10
Driver Alert Control	3	
Emergency Steering Support	2	1
Lane Support	7	
<i>Not prevented</i>	<i>11</i>	<i>21</i>
<i>Unknown</i>	<i>1</i>	<i>2</i>
<b>Total without double counting</b>	<b>22</b>	<b>40</b>

As shown in Figures 1 and 2, it was assessed that a total of 32 fatalities in and by Volvo cars could not be prevented with a V60 MY 2019. Among these 32 fatalities, it was found that 20 (16 under normal driving conditions) occurred in crash scenarios where at least one safety technology was relevant, although the current performance was estimated not to be sufficient to prevent the fatality. The most common ones were AEB head-on (n=10) and AEB with pedestrian and bicyclist detection (n=3), in cases where detection was highly likely but impact speeds were too high to be reduced to survivable levels with the current levels of autonomous emergency braking. In further six cases (five under normal driving conditions) the Volvo driver did brake and/or swerve to such an extent that the potential of AEB or Emergency Steering Support was considered to be minimal. In further three cases no technologies were estimated to be effective to any great extent due to extreme violations. Finally, the remaining three cases occurred in crash scenarios without any relevant safety technology. These

were a rear-end collision where a Volvo car was struck from behind by a PTW, a collision with a train at a railway crossing and a single-vehicle crash involving understeering in very slippery road surface conditions.

As shown in Table 3, eight fatalities (six under normal driving conditions) involved a Volvo car fitted with the optional Driver Support safety package. It was found that seven crashes occurred in crash scenarios where no relevant safety technologies were included in such safety package. These were:

- three unintentional lane drifting by an oncoming car, resulting in head-on collisions
- one intentional overtaking by the Volvo car, resulting in a head-on collision
- one reversing collision with a pedestrian
- one collision with a moose, resulting in the moose being ejected into an oncoming vehicle
- one single-vehicle crash involving understeering in very slippery road surface conditions

In one case, a pedestrian was killed by a Volvo car fitted with AEB with pedestrian detection. However, loss-of-control due to very slippery conditions had occurred prior to the collision with the pedestrian, which made the AEB detection and activation impossible.

Finally, it was also found that if the passenger car opponent had been fitted with ESC and Lane Support, further three fatalities in Volvo and six fatalities by Volvo cars could have been prevented, respectively. This would correspond to approximately 58-59% reduction of fatalities in and by Volvo cars. It should be also noted that most HGV in this study lacked all sorts of relevant safety technologies, and that ESC and ACC on HGV could potentially prevent further two fatalities in Volvo cars (for a grand total of 68% reduction, if combined with ESC and Lane Support on the passenger car opponents).

## DISCUSSION

The present paper analyzed Swedish in-depth data from fatal crashes involving modern Volvo cars (MY  $\geq$  2010) to understand how close to zero fatalities Volvo cars can get in Sweden by 2020. It was estimated that almost half of the current fatalities in and by Volvo cars could be prevented with a V60 MY 2019 safety equipped vehicle, which suggests that Volvo's vision will not be achieved in Sweden by 2020. However, it should be kept in mind that these results were based on retrospectively upgrading already relatively safe cars to the following generation. When this aspect is taken into account, it could be argued that reducing fatalities in and by a car by almost 50% through the introduction of only one new generation would be a very impressive achievement.

The present study has a number of limitations that need to be discussed. First of all, it should be clear that the results were based on two main assumptions. Firstly, Volvo cars MY 2020 would be fitted with the same safety technologies as the V60 MY 2019, and secondly, no major improvements in crashworthiness would be introduced between the analyzed Volvo models and Volvo cars MY 2020. While these assumptions do not seem unreasonable, it is evident that they directly affect the results.

STA in-depth studies are fully representative for Sweden, and possibly for Northern Europe at large. However, it is important to note that Swedish conditions may differ from other regions of the world. The Swedish market accounts for approximately 10% of Volvo's global market (Volvo Cars 2019b; Bil Sweden 2019). Therefore, caution should be used before generalizing the present results to a global level. Another limitation is that in this kind of retrospective analyses it is difficult to take into account any behavioral effects that may possibly follow from some technologies. On the other hand, analysis of the eight fatalities involving the Driver Support Package did not suggest any clear behavioral adaptation due to the presence of optional safety technologies. Clearly, it will be essential to follow up the real-life safety performance of the V60 model to understand how accurate the present results are.

Another important point to discuss is that the present paper exclusively analyzed the potential benefits of safety improvement in Volvo cars. In other words, no improvements among other vehicles, mostly passenger cars, but also in the road infrastructure were taken into account. This aspect can be seen as both a strength and a limitation at the same time. It is well-understood that the general car development is towards safer and safer cars, and that new cars from other manufacturers than Volvo are also fitted with several safety technologies, as shown in the latest Euro NCAP test results (Euro NCAP 2018). Some of these technologies could contribute to avoid fatalities in and by Volvo cars as well. For instance, unintentional lane drifting by oncoming vehicles could be prevented with Lane Support, thus preventing head-on collisions where the crash severity is too high for the current AEB head-on. At the same time, it could also be argued that the safety standards of Swedish roads are being constantly revised and that a portion of such head-on collisions with high crash severity will be progressively addressed by safer road infrastructure. All of these aspects suggest that the present results may be an

underestimation, at least in the long-term Swedish prospective. On the other hand, from a more global prospective it could be more difficult to achieve Volvo's vision by relying on a high market penetration of new safety technologies in other vehicles, and/or on a significant safety improvement of the road infrastructure. Therefore, it may be also a strength to focus on the potential benefits in Volvo cars to provide better guidance for future safety development.

It is also important to briefly discuss the relevance of different types and degrees of violations for the future development of vehicles. In the present study, 20% of the fatalities involved extreme violations, which is in line with previous findings on the frequency of extreme violations in all fatal crashes in Sweden (Lie et al 2001). In the present material, the majority of such extreme violations were excessive speeding. It seems reasonable to argue that in the future extreme violations will account for an increasingly proportion of all car fatalities, since crashes under normal driving conditions can be expected to be reduced to a larger degree by vehicle and infrastructural safety improvements. Therefore, it will probably become even more important in the future to detect and properly address reckless driving. Also, the potential of addressing milder (or even tolerated) violations such as driving at 90 km/h in an 80 km/h speed area should not be underestimated.

The present results are also relevant for the issue of automated driving. While such a vehicle implicitly does not drive recklessly, drivers of other vehicles might do, thus creating a problem for the automated car. It is also obvious that the automated car, if driven as the cars involved in the current study, would not be able to eliminate all fatalities with vulnerable road users. Obstructed pedestrians are a challenge also for automated cars. This could potentially partly be solved by cautious driving by the automated cars. The way the automated car is driven is therefore crucial for the performance of the safety technology.

Concerning the issue of safety management, it seems like a very good idea to set targets, develop technologies and follow up the results also for a car manufacturer. This gives opportunities for the outside community to monitor the progress and to understand what is needed from the rest of the community to act. This is well in line with both the road safety management system ISO 39001 (STA, 2015) as well as the Sustainable Development Goals (SDG) in the 2030 Agenda (UN, 2015). Communicating targets and outcome is a fundamental piece in both these instruments.

## Conclusions

In summary, by analyzing Swedish in-depth data from fatal crashes involving modern Volvo cars (MY  $\geq$  2010), it was found that:

- The yearly average number of fatalities in Sweden during 2010-2017 was 2.8 for occupants in Volvo cars and 5.0 for either occupants in other vehicles or VRUs impacted by Volvo cars, respectively.
- It was estimated that these fatalities could be almost halved with the safety technologies fitted on the following car generation, the V60 MY 2019. This would correspond to approximately 1.4 fatalities in Volvo cars and 2.6 by Volvo cars per year in Sweden.
- It was also found that most of the fatalities that could not be prevented with a V60 MY 2019, occurred in crash scenarios where at least one safety technology was relevant, although the current performance was estimated not to be sufficient to prevent the fatality.
- Only three cases occurred in crash scenarios without any relevant existing safety technology.
- These results are based on the assumption that the road infrastructure, speed limit and crash opponents would be unchanged. Clearly, taking safety improvements in the road infrastructure and other vehicles into account would result in an even higher reduction of fatalities in and by Volvo cars by 2020.
- In conclusion, regardless of whether Volvo's vision will be achieved by 2020 or not, it is very important to set road safety targets, develop new solutions and follow up the results, also for a car manufacturer.

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